Assessing Potentially Available Nitrogen in Saskatchewan using the Illinois Amino Sugar-N Test

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Abstract

A 3-year study conducted at four sites across Saskatchewan examined the responsiveness of wheat in different landscape positions to nitrogen (N) fertilizer additions. Failure to obtain a strong relationship between the traditional nitrate test and grain yield suggested the need for a soil test measurement that can more accurately predict the N-supplying power of a wide range of soils. The Illinois amino sugar-N (ASN) test, which estimates amino sugars as a potentially mineralizable fraction of soil organic matter, was performed on the study soils to determine if it could act as a more stable predictor of the responsiveness of crops to fertilizer N additions. Amino sugar-N was found to be significantly correlated to both unfertilized yield and yield response across all site-years. However, the correlation between ASN and yield response was variable between sites and landscape positions. Stepwise regressions developed to predict yield response indicated that spring nitrate levels, soil organic matter, and soil moisture are important in predicting yield response, although low R^2 values suggest a large amount of variability is still unaccounted for by these variables. Additional research will be required before the Illinois ASN test can be adopted to the Canadian Prairies.

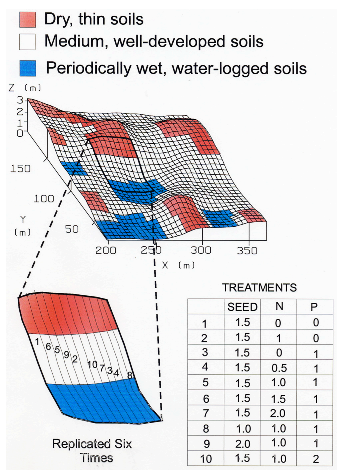
Introduction

Fertilizer recommendations in Western Canada historically have been based on spring inorganic nitrogen (N) levels, specifically nitrate (NO_3^-) (Soper and Huang, 1963). However, poor correlations between these soil test measurements and crop yields (Khan et al., 2001; Walley et al., 2001) have led to the search for other soil measures to better predict N-uptake and consequent crop yields. Inclusion of soil N availability indices that consider the potentially mineralizable soil N fraction should improve our ability to predict yield response and make fertilizer recommendations. The Illinois amino sugar-N (ASN) test is one analysis that has been used successfully to predict potentially available N by classifying soils as either responsive or non-responsive to fertilizer N (Khan et al., 2001).

A variable rate fertilizer study conducted across Saskatchewan (Pennock and Walley, 2000) examined the responsiveness of soils to N fertilizer additions. Subsequently, soils were analyzed for ASN as a preliminary step in assessing the potential application of the Illinois ASN test in Saskatchewan and across the Canadian Prairies. The objective of this study was to determine if ASN could improve predictions of crop yield by improving the relationship between soil N levels and crop yield. This was accomplished by first determining if a relationship exists between the two variables, and then assessing the factors that influence fertilizer responsiveness in Saskatchewan across a variety of sites and landscape positions.

Materials and Methods

The experiment was conducted over three growing seasons on four hummocky glacial landscapes chosen to represent major soil zones and agricultural areas of Saskatchewan (Table 1). The Outlook site was chosen to represent dryland irrigation production in the province. Landforms at each field site were segmented into upper-, mid- and lowerslope positions with the exception of the CLC site, which contained upper- and lowerslopes but no distinguishable midslopes. Plots were seeded to 'AC Barrie' wheat and fertilized with 0, 0.5, 1.0, 1.5, and 2.0 times the recommended N fertilizer rate based on standard soil test recommendations. Treatments were replicated in a randomized complete block design in which each block covered all landscape positions (Figure 1). Variable rate phosphorus fertilization was also studied in the experiment, although the following discussion is limited to N only. A more complete description of the experimental sites and methods can be found in Pennock and Walley (2000).



	SEED	N	P
1	1.5	0	0
2	1.5	1	0
3	1.5	0	1
4	1.5	0.5	1
5	1.5	1.0	1
6	1.5	1.5	1
7	1.5	2.0	1
8	1.0	1.0	1
9	2.0	1.0	1
10	1.5	1.0	2

Figure 1. Experimental design (Pennock and Walley, 2000)

Inorganic-N (NO_3^- and NH_4^+) was extracted from spring soil cores in each plot using the 2.0*M* KCl extraction method of Keeney and Nelson (1982), and analyzed using colorimetery. Soil organic carbon (SOC) was determined through dry combustion in a furnace at 840ºC. Amino sugar-N (0- to 30-cm soil depth) was determined using the Illinois ASN test as described by Khan et al. (2001).

Yield response for each replicate was determined using the formula:

Yield response=100*(Maximum yield — Unfertilized yield) / Unfertilized yield **(Equation 1)**

Inorganic-N values for each plot were averaged across each replicate. Pearson correlation analysis was used to determine the relationships between soil and yield parameters. Stepwise regression models were developed to predict yield response. The independent variables used in the models included NO_3^-, ASN, A-horizon depth, depth to carbonates, soil organic carbon (SOC), spring soil moisture ($Ø_v$), spring plant available moisture, crop water use, and growing season precipitation (GSP).

Results and Discussion

Table 1 confirms that each experimental site had unique soil and growing season properties. On average, the CLC site had the highest NO_3^-, ASN, and SOC values, while the Swift Current site had the lowest.

Table 1. Description of study sites

		Growing Season Precipitation cm	NO_3^- (0-60cm) kg ha^{-1}	ASN (0-30cm) mg N kg^{-1}	SOC (0-30cm) Mg ha^{-1}
CLC	**1997**	21.66	61.1	197 - 403	40 - 204
Thick Black Soil Zone	**1998**	31.60	49.8	129 - 395	46 - 192
hummocky glaciolacustrine	**1999**	34.73	83.6	89 - 492	23 - 205
Outlook	**1997**	29.45	60.7	143 - 213	34 - 78
Dark Brown Soil Zone	**1998**	34.90	41.4	123 - 243	40 - 94
undulating glaciolacustrine	**1999**	19.49	79.9	150 - 224	43 - 67
Swift Current	**1997**	18.30	26.1	62 - 172	18 - 59
Brown Soil Zone	**1998**	17.70	20.5	74 - 241	13 - 76
hummocky glacial till	**1999**	14.00	28.2	46 - 270	13 - 102
Watrous	**1997**	16.44	29.0	138 - 320	33 - 147
Dark Brown Soil Zone	**1998**	21.30	44.6	105 - 275	26 - 124
hummocky glacial till	**1999**	19.50	76.2	75 - 349	18 - 96

Amino sugar-N was significantly correlated to unfertilized yield and yield response although the strength of the relationships was not greatly improved over NO_3^-, particularly in the 0- to 30-cm depth (Tables 2 and 3). ASN was better correlated to yield response that to unfertilized yield in all landscape positions (Table 2). The strength of the correlation between ASN and both yield response and unfertilized yield followed the sequence upperslope > midslope > lowerslope.

At the CLC site, where SOC levels were the highest, there were no significant correlations between yield response and NO_3^- (Table 3), whereas the correlation between ASN and yield response was relatively strong. ASN may be a better predictor of responses to fertilizer when the high N-supplying power of the soil can overwhelm initial inorganic-N levels. Higher correlations between yield response and NO_3^- at Watrous may be a result of below average rainfall, which would limit the turnover of the organic-N pool. As suggested by Khan et al. (2002), the Illinois ASN test may be an unreliable predictor under non-normal growing conditions.

Table 2. Pearson correlations between soil N indices and wheat yield parameters within the entire data set and landscape positions.

	ALL DATA		UPPERSLOPE		MIDSLOPE		LOWERSLOPE	
	Unfertilized Yield	Yield Response	Unfertilized Yield	Yield Response	Unfertilized Yield	Yield Response	Unfertilized Yield	Yield Response
NO_3^- 0-30cm	.493**	-.455**	.477**	-.425**	.664**	-.537**	.442**	-.461**
NO_3^- 30-60cm	.194**	-.034	.585**	-.534**	.076	.283*	.237*	-.266*
NO_3^- 0-60cm	.409**	-.286**	.551**	-.494**	.294*	.048	.370**	-.396**
ASN 0-30cm	.399**	-.519**	.526**	-.651**	.329*	-.476**	.262*	-.462**

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

Table 3. Pearson correlations between soil N indices and wheat yield parameters within sites.

	CLC		OUTLOOK		SWIFT CURRENT		WATROUS	
	Unfertilized Yield	Yield Response	Unfertilized Yield	Yield Response	Unfertilized Yield	Yield Response	Unfertilized Yield	Yield Response
NO_3^- 0-30cm	.539**	-.233	.484**	-.429**	.716**	-.509**	.527**	-.448**
NO_3^- 30-60cm	.239	-.248	.785**	-.668**	.401**	-.048	.339*	-.435**
NO_3^- 0-60cm	.508**	-.266	.664**	-.577**	.651**	-.306*	.490**	-.467**
ASN 0-30cm	.455**	-.525**	.403**	-.393**	.714**	-.552**	.527**	-.338*

**Correlation is significant at the 0.01 level
*Correlation is significant at the 0.05 level

Interestingly, the data suggests that sampling to 60 cm (Soper and Huang, 1963) offered no advantage over the 0- to 30-cm depth for inorganic-N in the landscape positions (Table 2). However, at the Outlook site (Table 3), NO_3^- leaching as a result of irrigation was evident as indicated by the high correlations between yield and NO_3^- at the 30- to 60-cm depth as opposed to the 0- to 30-cm depth. Similarly, the 0- to 30-cm depth used for ASN may not adequately capture the depth of N influence at that site.

The parameters included in the stepwise regressions developed to predict yield response were not consistent between sites (Table 4). This indicates that the interaction of these parameters at each site have differing effects on wheat yield. In a stepwise regression variables are entered into the model if their inclusion significantly ($p<0.05$) improves the model R^2, and are removed if their removal does not significantly ($p<0.1$) decrease the R^2. Low model R^2 values indicates that although a range of predictor variables was applied to the model, the parameters were unable to account for very much of the yield variability at each site. Walley et al. (2001) found that yield response to N fertilizer was relatively unpredictable between years and landscape positions, and that this variability can be attributed in part to the dual role of N in both grain yield and protein increases.

Table 4. Results of stepwise regression equations of study sites for prediction of yield response.

	Parameter estimate	Standard error	F-value	Partial R^2	Model R^2
CLC					
Intercept	184.64	28.674			
SOC (0-15cm)	-1.476	0.337	16.484*	0.327	0.327
NO_3^- (0-60cm)	-0.613	0.279	11.583*	0.086	0.412
Outlook					
Intercept	16.432	50.124			
GSP	3.388	1.261	42.598*	0.450	0.450
NO_3^- (30-60cm)	-2.614	0.999	27.116*	0.065	0.515
Swift Current					
Intercept	275.83	28.249			
SOC (0-30cm)	-2.903	0.577	25.322*	0.327	0.327
Watrous					
Intercept	64.139	49.506			
NO_3^- (0-60cm)	-1.044	0.242	14.510*	0.218	0.218
ASN	-0.404	0.122	10.671*	0.077	0.295
θ_v (0-30cm)	4.559	1.85	9.844*	0.076	0.371

*significant at the <0.0001 level

Summary

Wheat yield response was a function of spring inorganic-N (NO_3^-), soil moisture (growing season precipitation, volumetric water content), and soil organic matter, although the contribution of any single parameter varied between sites. Relatively low R^2 values for the yield response functions indicates there is still a large amount of yield variability unaccounted for by any of the predictor variables. The correlation between ASN and yield response was variable between sites and landscape positions, indicating that ASN may not be an applicable measure of soil N fertility across the entire province of Saskatchewan. Additional research will be required before the Illinois ASN test can be adopted to agriculture production in Saskatchewan.

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